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PREVENTION OF ACCIDENTS IN SME´S

How do you prevent something you don´t know will happen?

Kirsten Jørgensen[1], Nijs Jan Duijm[2], Hanne Troen[3]

Abstract

When the accident has happened, everyone seems to know what should have been done to prevent it, but knowing how to prevent it beforehand is an incredible difficult task. During the past 5 years, a Dutch project has developed a risk assessment model for occupational accidents, based on an analysis of more than 10,000 serious accidents in the Netherlands, along with a comprehensive assessment of exposures. For the exposure assessment, data was collected on how often and how long workers perform certain actions and how the way they did it could be linked to the accident analysis. This for the first time ever makes it possible to determine the real risk of ordinary occupational accidents with respect to fatality, permanent and serious injury. This can be done at the level of industry sectors and type of job, as well as for any kind of job or activity. In Denmark we created a project in which we developed a method to observe and document the activities and risks in small enterprises, on the basis of the Dutch study. The co-operation between the Dutch and Danish projects has resulted in a very useful web-based risk assessment tool, which towards June 2009 will be accessible in Dutch, English and Danish. This tool can be used to obtain information, for both industry sectors as well as individual jobs, on real occupational risks divided into 64 categories, along with those safety barriers that are most effective to prevent accidents. The method has been tested in the Danish project in a series of small enterprises covering observations of about 120 man-days. These observations demonstrated that maintaining barriers against accidents can only partly be managed by the employer. Especially in enterprises with employees normally working outside the establishment, the daily safety assessment needs to be assigned to the individual employee, and he/she has to do this safety assessment ad hoc, responding to frequent changes in his/her working conditions. This is especially the case for jobs in building and construction, but also in many other enterprises with service or sales activities. The results of the Danish project is an application of the Dutch findings to describe what risks and safety barriers are most important for small enterprises in some industry sectors and jobs. Based on this knowledge, we can formulate requirements for, 1) what can and should the employer take care of; 2) what essential instructions and training should the employees receive; and 3) which specific considerations should the employee always have

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before starting an assignment. Even though this project provides the opportunity to calculate the real occupational accident risk and to identify the most relevant safety barriers, it is questionable whether this will change anything at all for a single person. There will probably be very few people from SMEs that will perform calculations or will look for this information. The question is how to disseminate this new knowledge, how to arrive at an understanding, and how to get apply it to real life. This challenge persists.

Background

About 178,000 enterprises with employees are registered in Denmark, as well as 121,000 one-man enterprises. Amongst those enterprises with employees, 85% have less than 20 employees, 10% have between 20 and 50 employees, 3% have between 50 and 100 employees, and only 2% have more than 100 employees[4]. This means that the safety efforts aimed at general risks should be targeted at small enterprises.

Small enterprises often have, considering their operations, a large potential for action and a good ability to adapt to changes in the conditions of daily life (Hasle & Limborg, 2004), which also is the advantage that makes them able to be very flexible in their management of tasks and thus warrants their existence in the labour market. The owner/manager in many cases is also the founder and “father” of the product as well as the structure of the enterprise. That is why his conception of product quality, precision, tempo, order and norms are the basis of the safety culture of the entire enterprise (Hasle & Limborg, 2004). Therefore, it is still the case that safety begins from the manager and whether he decides that safety should be an important parameter in his enterprise, regardless of whether the enterprise is big or small. Safety initiatives in small enterprises based on participants have been successful in several Asian countries, which on the face of it seem to be of a general nature (Kogi, 2006). Other initiatives that are supported are for example the German “Employer Model” (Eichendorf, 2001) and the Danish project “Control of Order and Safety” (Hasle & Limborg, 2004).

The first problem one encounters with regards to enhancing safety in small enterprises is the difficulty to create an understanding and insight in smaller employers that they should prioritise safety, because their own experiences are that accidents do not occur and that it is going well (Walters 2001). But when and if the manager decides that safety should be a priority he needs access to easily available information on what risks he should focus on and how he should act accordingly (Kogi, 2006, Halse et al, 2009). He generally has no energy, knowledge or base of experience for seeking knowledge in several locations and has no resources or people to help him within the framework of the enterprise to manage a safety function. At the same time, he needs his employees to be able function independently, i.e. that they during their basic training have gained an insight on how to work safely, as well as knowing how to plan their work (Vickers et al, 2003, Eakin et al, 1998). Surveys show in this context that many smaller employers find it difficult to convince their employees that safety is crucial and that they must

[4] Danmarks Statistikbank, ”Erhversstatistikken for 2007”

observe risk and act reasonably in regards to safety (Vickers et al, 2003). They consider it too difficult to supervise, because they cannot be where their employees work all the time. This is especially the case in the trades where the work tasks are done away from a home address, such as construction and contracting, transportation and agriculture. It can be helpful for both parties to have a tool for seeing risks and observing barriers, as well as being aware of necessary provisions and measures. It must be easily available as there are few resources for considering anything but the task at hand. The goal should be to achieve skills in the employees that make the way in which he/she considers how a task is done fully integrated with doing it safely. This demands a general understanding of tasks and the job. In the many tasks and jobs that take place away from the home address of an enterprise, meaning geographical locations other than where the employer has an office, there are distinct requirements for the employees to each day consider new surroundings and new work conditions (Jørgensen et al, 2008). In the small enterprises the worksite can change on a daily basis and possibly even several times each day. It is not physically possible for an employer to visit all such worksites and assess the safety there. In such cases he must be able to trust that the employee is able to do this himself, while also attending to customer commitments. The independence and self-management with regards to work safety therefore becomes particularly necessary for employees in many small enterprises. It demands of both the employer and employee that they have considered the safety standards and how the employee should act, that the basis from the home enterprise is acceptable with regards to equipment, tools, instruction, time and work preparation and that the employee has been told how to act, what to be aware of and what his general behaviour should be like.

Theory

The analysis of accidents is an analysis in hindsight as it is done after the accident has happened. The accident analysis can show several direct and indirect causes where to a large extent it is the fact that the causes occur simultaneously that makes the accident happen, rather than the presence of one single cause (Rasmussen, 1997, Jørgensen, 2002). But exactly the fact that a single cause not necessarily leads to an accident, but only when other causes occur at the same time, makes it difficult to point to the actual “culprit” and makes it hard to perceive causes, which in one situation mean nothing and are crucial for a different accident to happen.

Perhaps that is the reason why man’s actions and choices come under scrutiny when an accident has to be explained and the “cause” located. There has been focused a lot on human errors and mistakes, where a differentiation is made between conscious mistakes and unconscious, as well as between errors in the workmanship, errors in the memory, wrong choice of method, misunderstandings and lack of knowledge (Rasmussen, 1987, Reason, 1977) This perception of the different ways in which humans are mistaken and act erroneously have been seen in a framework of explanations and conditions for why people make mistakes due to the situation and context (Reason 1997). Organisation, decisions and work conditions affect partly what risks are present, but also if the necessary barriers to prevent risks leading to accidents are present (Reason 1997).

This brings us to consider the risk understanding and risk perception as important elements for man's possibility of acknowledging risks and knowing what dangers they hold and what consequences an accident can have. Basically, man is not particularly good at, or has the possibility of, assessing his own risk (Lin et al, 2007). Some risks are assessed too high and some too low, and it seems that many other factors in our lives and surroundings affect what we understand and acknowledge. This occasionally has the effect of us misunderstanding a situation or simply being mistaken with regards to an accident as a consequence (Lin et al, 2007). It is crucial to gain an understanding and acceptance of the paradox that one does not understand an accident and its causes till after the accident has happened, but that it must be prevented before it happens. Quite often, accident preventive initiatives in enterprises are to investigate the accidents that happen, and to then act on the concrete causes as evidenced by the investigation. But this kind of reaction has turned out to have a limited effect and over time practically none at all (Krause, 1995). A far better preventive effort is achieved when management makes a decision of wanting a higher degree of safety and a more specifically targeted effect of the safety efforts. It is even better if the management is able to create a culture within the enterprise of having the employees participate in creating a continuous improvement of safety (Krause, 1995, Glendon et al, 2007, Flin and Yule, 2004).

The knowledge about risks and causes of accidents needed in such a process must be gathered from surveys and analyses of the many accidents, but in a way in which you can gather from it the generically fundamental causes of the accidents happening, as well as generic provisions, i.e. barriers that can prevent risks from becoming accidents. But the usage of that generic knowledge is crucial for the desired results to be achieved (Krause, 1995, Hollnagel, 1999, Hale & Guldenmund, 2003).

The risks commonly focused on specifically are those that could result in very serious consequences if they develop into an accident. Especially the spectacular risks of many people simultaneously being exposed to risks have been focused on and of course for good reason (Lin et al, 2007). But the fact is also that the so-called banal though more normal types of accidents are very frequent and can have serious consequences for the individual person (Jørgensen, 2008). Far more people die because of such common risks than do because of what is often characterized as "high-risk" areas. This is a great challenge with regards to doing something about these common risks, rather than neglecting the risks focused on presently (Jørgensen, 2008).

Three types of instruments management can use in a proactive prevention strategy will be highlighted in the following: 1) The technical and organizational barriers designated to prevent accidents from happening. 2) The situation-specific awareness to be created in people, giving them the possibility of making the correct choice. 3) A method of gathering and spreading knowledge about risks and their barriers through so-called "message maps."

With regards to the barriers, a differentiation can be made between active and passive barriers, where active ones demand an active action from people to function, while the passive ones function by their presence alone. The barriers can be further split up into those that seem preventive, those that protect and those that reduce the damage. The preventive barriers ensure that no incidents that can lead to accidents will occur, while the protective barriers ensure that no harm will be done, even if an incident occurs and the limiting barriers contribute to minimizing damage (Hollnagel, 1999). Furthermore, it can be useful to divide barriers up into technical barriers, behaviour-influencing barriers and combinations of these (Hale & Guldenmund, 2003).

The situation-specific awareness can be defined as: "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 2000). If you do not understand what the objective of the individual person is in a given situation, the information in the environment will carry no meaning. Added to this is that presupposition and expectation influence the situation-specific awareness (Endsley, 2000). Actually, people must rather act from whatever holds the direct information in the situation. They must be able to combine information and imagine incidents that affect what their experiences are based on. They must be proactive, not merely reactive. They must act from objectives and be able to do so with a certain automatic and knowledgeable behaviour (Endsley, 2000).

A tool for creating an overview of barriers as well as risks and appropriate actions, and thus heightening the situation-specific awareness, is the development of message maps (Flin et al, 2006). Message maps have been developed to create an overview of which users of information need what information, which then enables the individual persons to take decisions by themselves and act according to their own needs. Furthermore, message maps can be used as a mean for creating a situation-specific awareness, in a decision-making process as well as in communication and cooperation, including establishing in what way managers can support this process (Lin & Petersen, 2007, Flin et al, 2006).

These tools can be used in connection with proactive accident prevention by those small enterprises if they are targeted at the accident risks that are tangibly present. There are methods for creating greater likelihood of the situation-specific awareness being correct and that there will be acted appropriately, such as knowing what observations to be aware of, what barriers need to be present for everything to progress properly and what actions are required if the conditions are not as they should be. This is not meant to remove the proactive prevention from managerial responsibility, but on the contrary to support the managerial responsibility with concrete tools, especially useful for small enterprises.

Methods

In 2003, a big Dutch project called WORM was initiated by the Dutch Ministry of Social Affairs and Employment. WORM is an abbreviation of Workgroup on the Occupational Risk Model and was meant to develop a basis for calculating the risk of work accidents in any task within the world of work. The background of the project was the work with "I-RISK – A quantified integrated technical and management risk control and monitoring methodology," which was the result of a European research project concluded in 2000 (European Commission, 2000). The

I-Risk methodology was created for use in high-risk areas and based on assessing risks from dangerous chemicals in processing plants. The objective was to be able to prevent big accidents involving dangerous chemicals and to limit the consequences, should such an accident occur. The WORM project had a similar objective for work accidents, namely to develop a method and an electronic program to support a management in the decision making process towards preventing work accidents (Ale B., 2006, WORM Metamorphosis Consortium, 2008).

The basic model for WORM is a bowtie model (butterfly model), which is a model combined of fault tree analysis and a cause-and-effect analysis, see Figure 1. The bowtie model is build around a center event. The choice of center event is critical to the analysis as any unwanted incident can be a center event, where the analyses of causes as well as consequences start from. Actually, different types of unwanted incidents can be perceived as being either causes or effects, entirely dependent on where the center event is placed. However, as soon as you have established the center event the description of causes and effects will solely have to do with the center event in question.

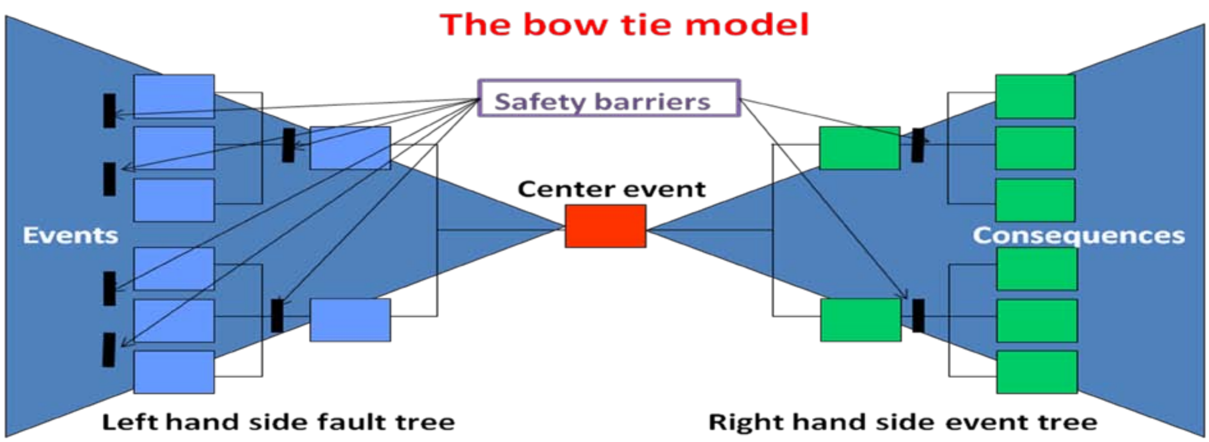

Figure 1 - General lay-out of a Bowtie description

A bowtie analysis is in principle only a description of event chains leading up to the center event in question, and illustrates the possible effects of that particular center event. By combining the analyses with traditional fault tree analyses and cause-and-effect analyses one can identify barriers that have been missing or not working for each and every link in the event chains.

Prevention of accidents is in principle about avoiding or minimizing the effects of center events, but to achieve this goal, preventive action must be aimed at making sure the barriers are present and functional. This means that a management prioritization starts from the far right hand side of the model and has its room for action in the far left hand side of the model. What the butterfly model does is to create the image and coherence between these poles. The philosophy of the WORM project is that as soon as an image of these contexts has been created it will be possible to calculate the risk and determine what preventive initiatives would be most appropriate to do in order to lower the risk.

The WORM project developed 64 butterflies based on analyses of more than 9,000 accidents with either serious or fatal consequences. The analyses have been made through a “storybuilder” method, which will be described in section 4.2. The butterfly model thus creates coherence between the occurrence of certain causes and the likelihood of certain consequences. In the WORM project three types of final consequences have been calculated with: 1) Death; 2) Invalidities; 3) Serious, but curable injuries. The utilized data concerns work accidents that have led to hospitalization. The right hand side of the butterfly analysis then comprises the consequential process, which the given center event lead to, including the conditions that could contribute to increasing or limiting the seriousness of the injury. The safety barriers found on the right hand side are the so-called protective barriers that prevent or minimize the injury of a given central event. The left hand side of the butterfly analyses comprises all cause chains that influence the occurrence of the central event. The safety barriers here are the preventive barriers meant to prevent the central event from happening. In WORM an understanding has evolved of the fact that both primary safety barriers (PSB) and supportive safety barriers (SSB) exist. What is more, all these safety barriers can be tied to information (PUMMs) on them about whether they are: 1) Provided, 2) Used, 3) Maintained or 4) Monitored. The safety barriers can be examined further for how the organisation deals with the barriers in relation to procedures/rules, equipment/tools, availability, qualifications/training, communication/knowledge, motivation/commitment and conflict resolution.

A crucial element of the analyses in “storybuilds” and subsequent bowties is what safety barriers have failed and hence has caused accidents. In some cases the safety barriers are easy to assess while they in other cases need more detailed information. Furthermore, it is necessary not merely to identify the safety barriers, but to also examine what qualities they have and what factors affect this. The factors that affect the quality of the safety barriers and thus influence the likelihood of an accident occurring has been termed Probability Influencing Entities (PIEs) meaning factors that can influence the likelihood of failure of a safety barrier. The idea is that if PIEs are entirely in order then the safety barriers will be as well and the risk of an accident happening is therefore low, while if the PIEs are lacking, not in order or present, the safety barrier will be bad and the risk of an accident happening will be high. Part of the Danish project has been to develop an easy-to-use tool for helping an enterprise register what activities the different tasks are comprised of, including what risks are innate to the tasks, as well as what condition necessary barriers are in during the execution of the activities. The tool is a program installed on a PDA which means that you simultaneously can register time usage, activities, risks and barriers. This knowledge can later be entered into the Dutch WORM program for calculating the real risks of respectively death, invalidity and other serious injuries.

The objective of the Danish project, however, is to make it easy for small enterprises to gain control of safety. A combination of activities in a trade of how the tasks are being done and a use of the Dutch data, including the knowledge of barriers and PIEs for concrete risks, makes up a good basis for creating objective-specific message maps for concrete trades. Thus, an opportunity is created for being very specific on what is important for the small enterprises to focus on, what the employees should learn and know, namely how to assess risks in their daily, often very diverse, work process.

Results

Classification of activities

The first result of the DanWorm project came when we were planning observations at the small enterprises. As we attempted to make registration simple, we discovered that it is possible to classify the 64 hazardous activities into three levels. The "zero" level consists of 4 groups as a main entry to all kinds of hazardous activity. Table 1 shows this essential entry to hazardous activities.

Table 1 "Zero" level of classification of activities to be registered.

A. The surface on which you move/work - concerns the risk of falling
B. Conditions at the work place - concerns your surroundings where there is a risk of being hit or hitting something, being hit by collapsing or falling objects, flying objects or similar
C. What you are working with – concerns the risk of being cut (sharp edges), jammed, crushed, injured by moving tools or chemicals etc.
D. Special dangers - concerns very specific and infrequent high risks like fire, explosion, drowning, poisoning etc.

Each of these main classifications have 2 – 5 subgroups, which then again have 2- 8 specific "hazardous activities" closely related to the specific 64 bowties in the ORM system (WORM Metamorphosis Consortium, 2008).

Table 2 Full classification of the hazardous activities in order to structure the observation and registration of these activities.

Level 0	*Level 1*	*Hazardous activity*	*Bowtie Code*
A. The surface on which you move/work	1. Working on height/falls	Placement ladder	01.1.1.1
		Fixed ladder	01.1.1.2
		Step ladder or steps	01.1.1.3
		Rope ladder	01.1.1.4
		Mobile scaffold	01.1.2.1
		Fixed scaffold	01.1.2.2
		(De)-installing scaffold	01.1.2.3
		Roof	01.1.3.1
		Floor with different levels	01.1.3.2
		Fixed platform	01.1.3.3
		Mobile platform	01.1.5.1
		Non-moving vehicle	01.1.5.2
		Other	01.1.5.3
	2. Working on same level/fall	Working near hole in ground	01.1.4
		Walking on floor,	01.2
		Walking on stairs	01.3
		Walking and overloading	25.2

Level 0	*Level 1*	*Hazardous activity*	*Bowtie Code*
B. Conditions at the work place	3. Working where objects can fall down	Cranes and loads	3.1
		Mechanical lifting	3.2
		Loadings on vehicle	3.3
		Manual handling	3.4
		Other ex stored objects	3.5
	4. Working where objects can be flying around you	Flying objects from machine or hand tool	4.1
		Flying objects under tension or pressure	4.2
	5. Working where you can be hit against, hit by or hit between objects	Struck by moving vehicle	2.0
		Working in open air with blowing wind	4.3
		Passing round, rolling or sliding objects	5.0
		Passing others working with hand tools	6.1
		Passing others who are handling objects	6.2
		Passing nearby hanging or swinging objects	8.2
		Risk of being trapped between or against objects	8.3
		Risk of moving into objects	9.0
	6. Passing or working near-by bulk mass that could skid, collapse	Passing bulk mass	10.0
	7. Working with people or animals	Aggressive human being	20.1
		Aggressive animals	20,2
C. What you are working with	8. Technical equipment	Handheld tolls	7.0
		Operating machines	8.1.1
		Maintaining machines	8.1.2
		Clearing machines	8.1.3
		Cleaning machines	8.1.4
	9. Vehicle	In or on moving vehicle	11.0
	10. Electricity	Risk ofr electrocution by tools	12.2
		Electric work	12.3
	11. High or low temperature/heat or cold	Cold or warm objects surfaces	13.0
		Hot work	17.1
	12. Chemicals	Working near open containments	14.1
		Working near closed containments	14.2
		Adding, removing or opening closed containments	15.1
		Transport of closed containments	15.2
		Closing closed containments	15.3
	13. Lifts and loads	Handling heavy objects	25.1
D. Special dangers	14. Risks of high voltage	Working with high voltage	12.1
	15. Risks of fire	Working close to or with open fire	17.2
		Fire Fighting	17.3
	16. Oxygen problems incl. Water, lack of oxygen and drowning	Working in confined space with hazardous atmosphere	22.1
		Working with breathing apparatus	22.2
		Working in, on or under water	23.1
		Working close to water	23.2
	17. Risks of explosion	Nearby or working with explosive equipment, objects under pressure	27.1
		Nearby or working with explosive vapor or gas	27.2.1
		Nearby or working in explosive dust	27.2.2
		Nearby or working with explosives	27.2.3

Level 0	*Level 1*	*Hazardous activity*	*Bowtie Code*
		Nearby or working with chemical - including exothermic - reaction	27.2.4

Table 2 shows the full classification system of the 64 hazardous activities. For each hazardous activity, the safety barriers are identified as primary and support barriers. Furthermore the PIEs are identified for each barrier. An assessment of the risk thus is connected to an assessment of the conditions describing how good the barriers are for the activity in question. Table 3 provides an example of the safety barriers to “fall from height – placement ladder” and their PIE questions.

Table 3 Example of the assessment of the criteria that affect the probability of accidents, in this case working/standing/climbing on a placement ladder (WORM Metamorphosis Consortium, 2008).

Activity hazardous	*Primary safety barriers*	*Support safety barriers*	*Evaluation criteria – PIE´s*
Work at placement ladders/ Risk of falling	1. The ladder strength	1. The type of ladder and the strength	Conditions of ladder steps
			Inspection of ladder capacity and length
			Maintenance and storage
			Cleaning
	2. The ladder stability	2. The placement and protection of the ladder	Placement on the ground
			Placement at the top, angle
			Protection against traffic
	3. The user stability	3. The ability of the user to stay on the ladder	Position on the ladder
			Personal condition
			Use of both hands to hold onto the ladder
			External forces influence
			Appropriate movements

The DanWORM project developed a tool for doing the observations in real life activities with the purpose of making it easy for the enterprise to collect the necessary information about the jobs, activities, safety barriers and PIEs. This tool was created as a program to be used on a PDA with a step-by-step procedure to lead the observer through the decisions that must be made. Figure 2 shows one example of the screen on the PDA, for the evaluation of the barriers.

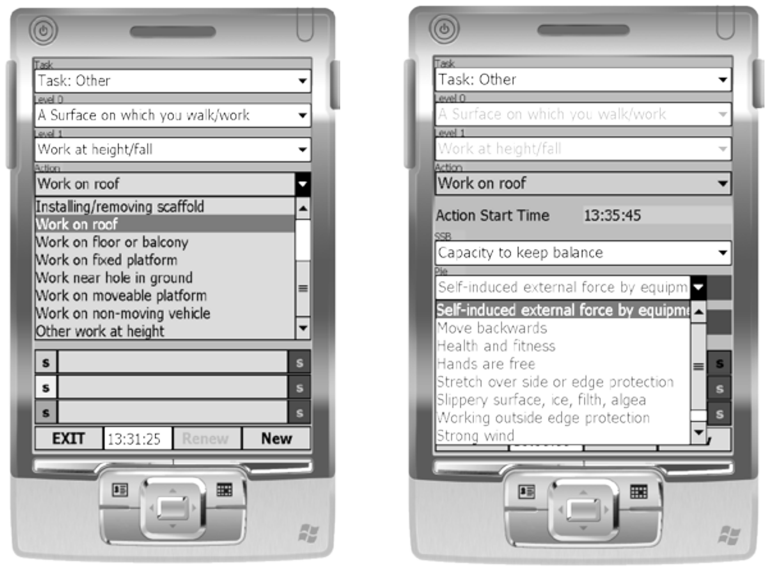

Figure 2 Example of the PDA interface selecting an activity to be recorded and afterward when selecting the status of the Probability Influencing Entities (PIEs)

The first screen of Figure 2shows in an example of the PDA interface when selecting an activity to be recorded. The selected activity "working on roof" belongs to group A (Surface on which you walk/work), Subgroup 1 (Working at height/fall). Within this subgroup there are eight possible actions. The second screen of Figure 2 shows in an example of the PDA interface selecting an activity to be recorded and afterwards when selecting the status of the Probability Influencing Entities (PIEs) that affect the quality of the Secondary Support Barrier (SBB): "Capacity to keep balance" for the activity "working on roof" (cf. Table 3). There are eight PIEs for this barrier. Each of the PIEs can be given the status "correct" or "faulty" for each recording of an activity.

The PDA application transpired to be very easy to use for a person accustomed to IT. It has been easy to record the observations even when the activities and barriers change quickly for shorter or longer periods. The next step will be to let new untrained persons use the tool and then to receive their feedback.

We note that, though it is not difficult to use the tool or to make the observations, it is difficult to fully understand what to look for and to gain an overview of the many details. We conclude therefore, that the observations still require certain knowledge of safety and health issues. The observations must cover the entire work day and also include those activities that are not normally considered to be especially hazardous.

We must also realize that it is time-consuming to follow people around for several work days. One could of course ask people what they do and how, as was done in the Dutch survey to find data on the exposure. But our experience is that the observed persons do not really know themselves. They find that they do many different things which change all the time. Even when we ask them how much time they spend on the main tasks in a year, their answers can be very vague.

One set of observations was carried out for carpenters engaged in construction and maintenance of small residential buildings. The other set was carried out for real estate caretakers. The occupations were chosen on account of their generally high rate of injury. We found that these jobs are characterized by the fact that the work situations and work conditions change from day to day and hence are unpredictable.

The attitudes towards safety and health in the enterprises involved in this project are very similar to what we gathered from other research results. The employees do not recognize the risks they are exposed to; doing the job is their first priority; and the employer expects them to look after themselves. On the other hand, the enterprises that actually agree to participate show an interest in safety issues and want to learn how to prevent injury. They ask questions about safety and health issues and are willing to take good advice.

Workplace assessments

A second result of the observations and the interviews can be illustrated by the workplace assessment of the carpenter enterprise. Because the work varies a great deal it makes sense to divide the workplace assessment into two parts: a general part that covers general risks and preventive actions where the employer has to initiate accident prevention; and a second part that covers the risks which the employee has to be aware of before he starts on a new task.

It is impossible for an employer of such a small enterprise to make a full risk assessment of every single one of the new task his employees have to do. Of course he can make demands and give instructions, as well as provide the tools and equipment that the employees need to work safely, and he can inspect and control the work that has to be done.

The first general risk assessment for a small carpenter enterprise contains a proposal for a plan for safety and health, and recommends procedures and equipment for:

1. *Cleaning tools, machines, vehicles, workplaces*
2. *Hoisting of materials*
3. *Placement of electrical wire*
4. *Placement of handheld tools, when not used, in storage or under transport*
5. *Maintenance of tools and machines*
6. *Safety equipment for limiting exposure to dust*
7. *Safety gardening on machines*
8. *Working with windows or glass materials*
9. *The availability of personal safety equipment*
10. *The use of mobile telephones during transport*

The second risk assessment targets the employees and contains a one-page and 10-point risk-awareness program to be ticked off. This takes just a couple of minutes when the employee begins a new task. The 10 points are the following:

1. *Safety at scaffoldings: check the railing, the floor, the cleaning, the distance between the scaffolding and the house, the manhole and evaluate the risk of falling in relation to your own well-being.*
2. *Safety at ladders: check the maintenance, the stability, the strength, the length, the firmness of the ladder's footing and evaluate the risk of falling in relation to your own well-being.*
3. *Safety when working on a roof or at heights: check the railings, the floor, fall resistance, the surface strength and evaluate the risk of falling in relation to your own well-being.*
4. *Safety at tools and machines: check the safety guards, maintenance, the placement of materials, and the placement of electrical wire.*
5. *Personal safety protection: evaluate the needs and the availabilities.*
6. *Safety in manual handling: check for heavy lifting, the need for hoisting equipment, the right lifting technique, the use of equipment such as a platform or small stepladder to ensure a good working position,*
7. *Safety wherever you are walking: check the cleaning, the maintenance of the main road, the placement of materials, waste, wires, tools etc.*
8. *Safety in handling waste and waste removal: check the need for personal safety equipment.*
9. *Safety in transport both at the site and in the traffic: check the traffic behavior, the maintenance and cleaning of the vehicle.*
10. *Be conscious of acute risks in the working situation such as:*
    - *Sharp equipment, risks of being crushed or jammed, risks of being hit or being hit by something, fire risks, chemicals risks, dust risks, explosion risks, risks of materials collapse or fall, risks of slipping or irregular surfaces, risks of falls in general, risks from other road users.*

This list seems to be long, but with some training and everyday use the risk evaluation done by the employee in the concrete work situation becomes practicable and will not take long for the professional carpenter. Most professional carpenters would probably say that they do this all the time. In such cases, the list reminds them to be systematic in their evaluation. For the young carpenter with less experience the list can be a kind of checklist.

The need for both a risk assessment for the enterprise and the employer (as the legislation requires) and a list for the employee's own daily risk assessment has been very apparent in our observations. It is necessary to train the employees to handle their daily risk situation in a professional way. This does not equal divesting the employer of responsibility, but rather supporting the collaboration between the employer and his employees as well as qualifying the dialogue about working conditions. All risks of accidents can never be eliminated, but one can learn to handle the risk situations in a way that prevents the risks from leading to accidents.

Message maps

The third part of the results is a consequence of the theoretical work and the results mentioned above. The idea was to develop message maps for different risks as a basis for education and training using the information from the safety barriers and PIEs for each hazardous activity.

These message maps should be focused on both what the employer should be aware of and what the employee should be aware of.

An example of such message maps is illustrated in Figure 3. It illustrates what a message map for the risk of ”being hit by a movable object” could be like.

Hazard: Being hit by a movable object. **Barrier**: Controlling movable objects in the area		
Gather information	**Understand the information**	**Predict and react**
Where are the movable objects in the area?	Assess whether the movements could possibly hit you	Secure movable objects and their movement path
How do they move?	Assess whether the movements are varied and whether they should be adjusted	Adjust, signal, flag, communicate with your surroundings
Can their movement become uncontrollable?	Assess what could make the movements uncontrollable	Check the security devices and information to the surroundings
Can I be in the object’s movement path?	Assess how I should act to not be caught in the object’s movement path	Adjust your own behaviour

Figure 3 Example of a message map.

The simplest way for a small enterprise would be to start from its jobs’ specifications of what risks are important and then at least secure against these dangers. The individual enterprise, though, can also make its own assessments that can be either the simplest one, namely asking the employees, or the more complicated one of having a proper analysis done.

Risk profiles

During the observations of the carpenters, we recorded what tasks were performed by the carpenters. Those tasks were defined in collaboration with the carpenters so that the tasks were representative and in line with the carpenters’ own perception of their job. The outcome is presented in Figure 4. Using the PDA tool as described above the distribution of hazardous activities within these tasks was described, and by applying the results of the Dutch WORM tool, a typical risk profile for a carpenter (with the tasks as in Figure 4) can be estimated, which is presented in Figure 5. Though risk factors (PIEs) were recorded during the observations, this information is not included in Figure 5 – here it is assumed that the risk factors are similar as those based on the outcomes of the questionnaire investigations of the Dutch work force, which is referred to as the “Dutch National Average”.

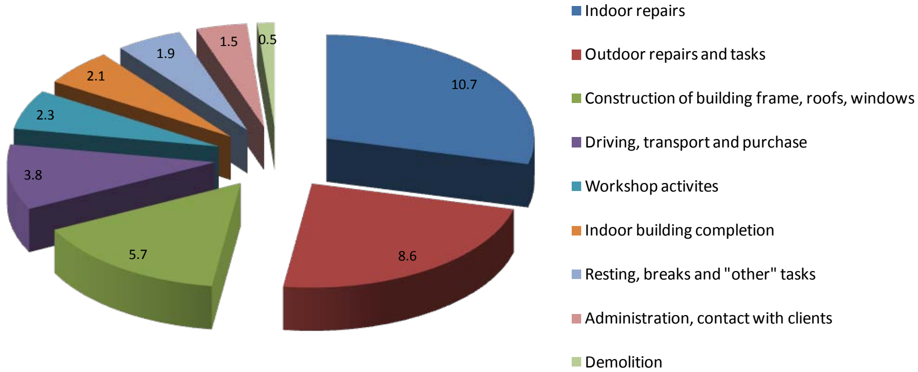

Figure 4 Allocation of work time to job-specific task for the observed carpenters (hours per week).

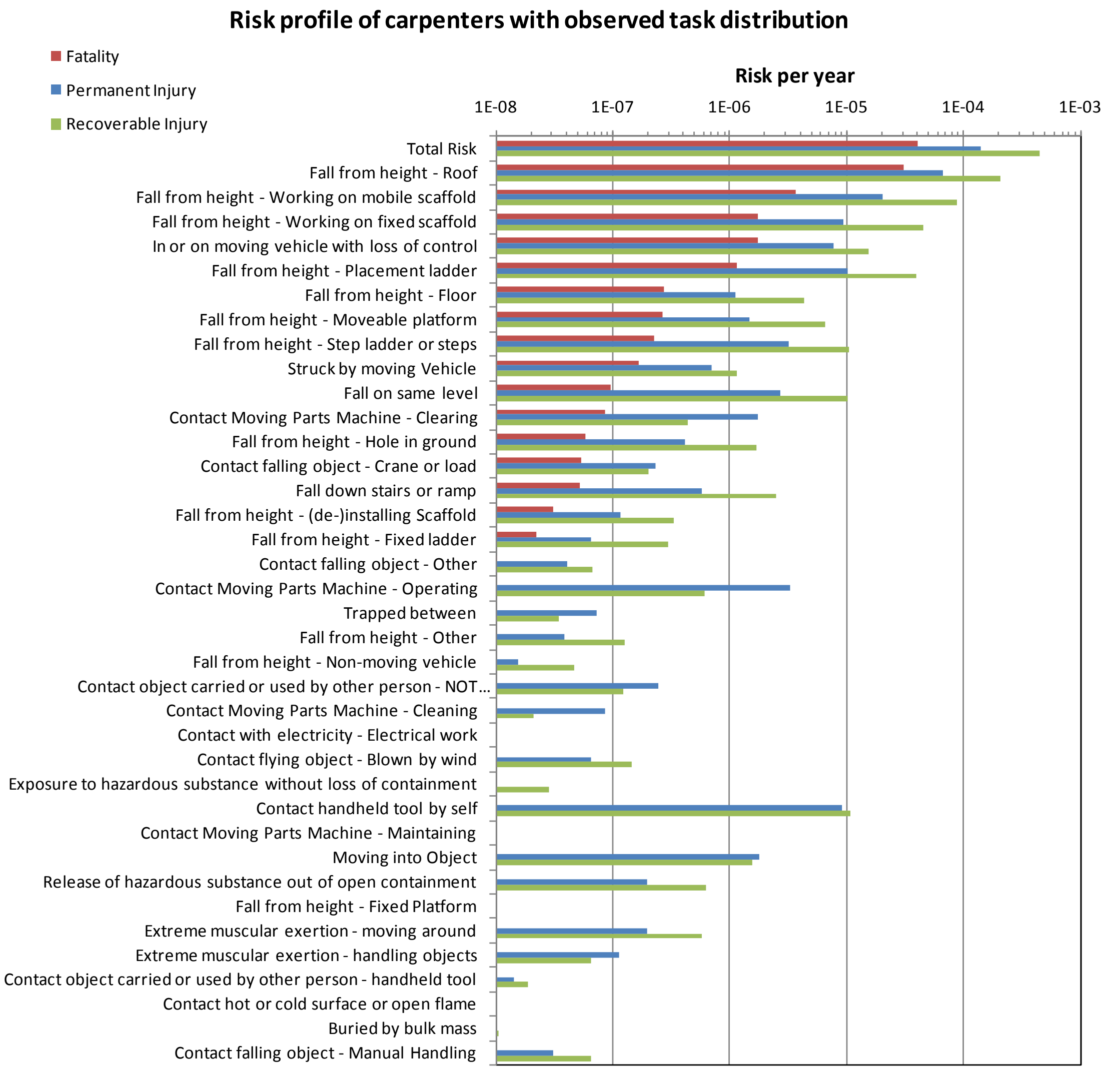

Figure 5 Risk for carpenters, assuming risk factors (PIEs) to correspond to Dutch National Average.

Summary of results

Figure 6 illustrates the final concept of the DanWORM project. It shows schematically the previously mentioned results. The top half shows the theoretical elements, background knowledge and tools, while the practical results can be summarised to be:

- What questions to ask when assessing the risks of accidents in enterprises
- What the employer must do to enhance the safety standard
- What instructions must be given to the employee
- What the employees must do to enhance the safety standard

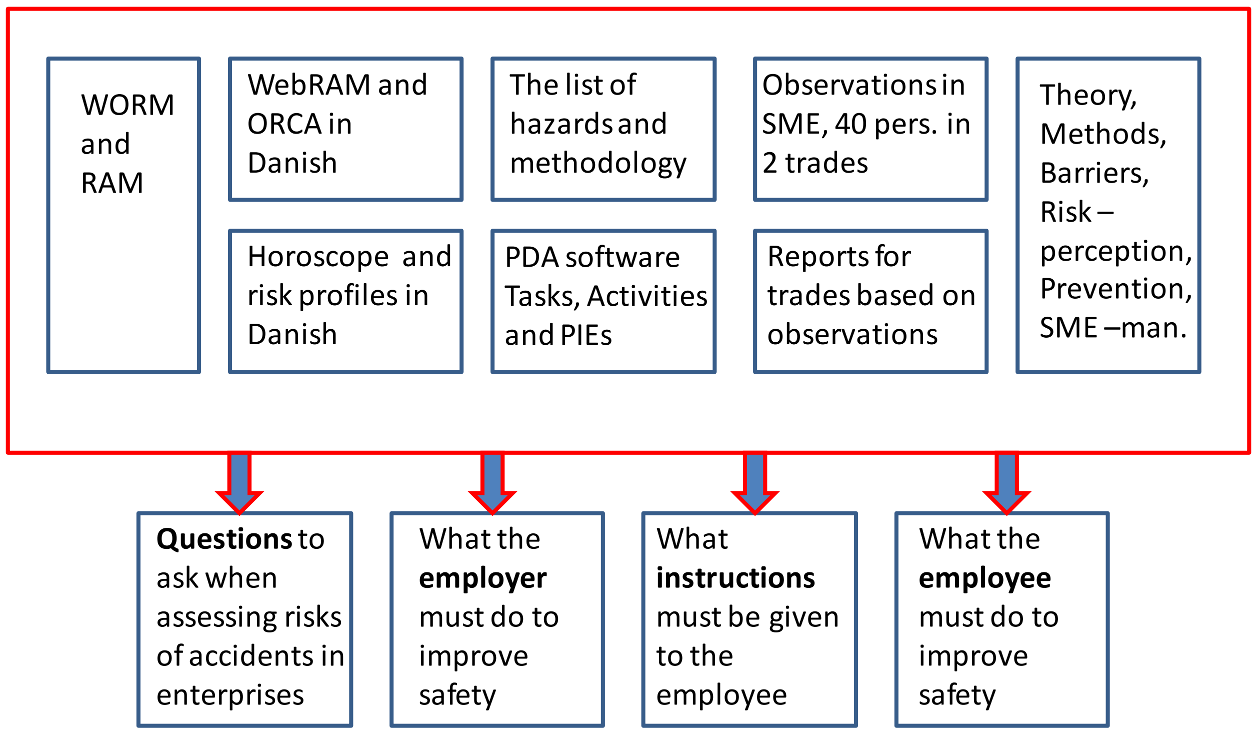

Figure 6 The concept for the final results of the DanWORM project.

Discussion

In the Dutch WORM project and the Danish DanWORM project, respectively, basic data for knowledge about risk of accidents in work sites and for assessments of this have been collected and investigated.

The material, however, is still difficult to assess and difficult to put to practicable use. Therefore more development of methods to utilize this comprehensive data is needed.

The Danish project has ensured that all tools and data are available in Danish and it has contributed to the possibility of making it accessible in other languages.

Furthermore, a simple three-step-level-classification has been found, cf. Table 1, which has turned out to be exceptionally suitable for risk observations and analyses.

It has also been obvious in the Danish observation that it is necessary to separate: what is to be expected of an employer to handle; what should be ensured have been taught and instructed; and finally what the individual employee himself must take care of to achieve a higher level of safety. This is supported by several other research results that indicate that it is not until safety is prioritized and created in cooperation between both employer and employee that a low risk of accidents is achieved continually.

The proactive prevention can then be assisted by tools such as message maps that can be part of the empirical data, which must be the centre of the proactive prevention.

How to transfer these results to both small and large enterprises afterwards is still not determined. This leaves a key question not answered by this project. In the small enterprises especially, there is not much awareness or interest in the safety problem, and they themselves declare that they are doing fine, and actually do not have time to do other tasks than those provided to them by their clients. The ensuing implementation therefore relies on communication.

References

Ale, B.J.M. (2006). The Occupational Risk Model – final report of the Workgroup on ORM, TUDelft , The Netherlands

Eakin J.M. and MacEachen E. 1998, " Health and the social relations of work: a study of the health-related experience of employees in small workplaces", Sociology of Health & Illness Vol. 20 No 6 pp. 896-914

Eichendorf W., 2001, "The employer model", BG, Germany

Endsley M.R. and Garland D.J., 2000, " Situation Awareness Analysis and Measurement", Mahwah, NJ: Lawrence Erlbaum Associates

Endsley M.R.,2000, " Theoretical Underpinnings of Situation Awareness: A critical review", Lawrence Erlbaum Associates

European Commission, 2000, " I-Risk – A quantified Integrated technical and management risk control and monitoring methodology", Directorate-General for Research, EUR 19320

Flin R. et al, 2006, " The Non-Technical Skills for Surgeons (NOTSS) System Handbook v1.2" University of Aberdeen, Scotland

Flin R., Yule S., 2004, " Leadership for safety: Industrial experience", Qual Saf Health Care 13(suppl II), pp 45-51

Glendon A.I., Clarke S.G., McKenna E.F., 2007, "Human Safety and Risk Management" – second edition, Taylor&Francis

Hale A. & Guldenmund, 2003, " Barriers and Delivery Systems", Worm paper ,

Hasle P. og Limborg H.J. , 2004, " Styr på Orden og Sikkerhed – SOS – Udvikling af metoder til ulykkesforebyggelse i små virksomheder, IPL-DTU, Danmark

Hasle P., Kines P., Andersen L.P., 2009, ”Small enterprise owners´ accident causation attribution and prevention”, Safety Science 47, pp 9-19.

Hasle P., Limborg H.J., Ledskov A., Nalholm E., 2004, ” Arbejdsmiljøarbejdet i mindre og mellemstore virksomheder – en litteraturanalyse”, IPL, DTU, Danmark

Hollnagel E., 1999, ” Accident analysis and Barrier Functions”, Project TRAIN, IFE

Jørgensen K. 2002, ”En taxonomi for Arbejdsulykker – en systematisk beskrivelse af årsagssammenhæng”, BYG-DTU rapport R-027, Danmark

Jørgensen K., 2008, “The dominance of accidents caused by banalities”, EVENT ANALYSIS AND LEARNING FROM EVENTS, 26th NeTWork Workshop,Steinhoefel near Berlin, August 28th -30th, 2008

Jørgensen K., Duijm N., Troen H., 2008, ” Accident prevention in SME using ORM”, Reviewed for Safety Science, not yet published

Kogi K., 2006, ” Advances in Participatory Occupational Health Aimed at Good Practices in Small Enterprises and the Informal Sector”, Industrial Health 44, pp 31-34

Krause T.R., 1995, ” Employee-Driven Systems for Safe Behavior – Integrating Behavioral and Statistical Methodologies”, Van Nostrand Reinhold Staff, ITP, USA

Lin I., Petersen D.D., 2007, “ Risk Communication in Action – The tools of message mapping”, EPA/625/R-06/012, United States Environmental Protection Agency, Cincinnati, USA

Rasmussen J., Duncan K., Leplat J.,1987, “New Technology and Human Error, John Wiley & Son,

Rasmussen J.,1997; “ Risk Management in a Dinamic Siciety: A modeling Problem”, Safety Science, vol 27, no2/3, pp 183-213

Reason J., 1997, “Managing the risks of organizational accidents”, Ashgate Publishing Company, USA

Vickers I., Baldock R., Smallbone D., James P., Ekanem I., 2003, ” Cultural influences on health and safety attitudes and behaviour in small businesses”, Research report 150, HSE BOOKS, UK

Walterts D.,2001, Health and Safety in Small Enterprises – European Strategies for Managing improvement”, SALTSA, Belgien

WORM Metamorphosis Consortium, (2008), “The Quantiffication of Occupational Risk - The development of a risk assessment model and software, RIVM, report 620801001/2008, Bilthoven, The Netherlands.